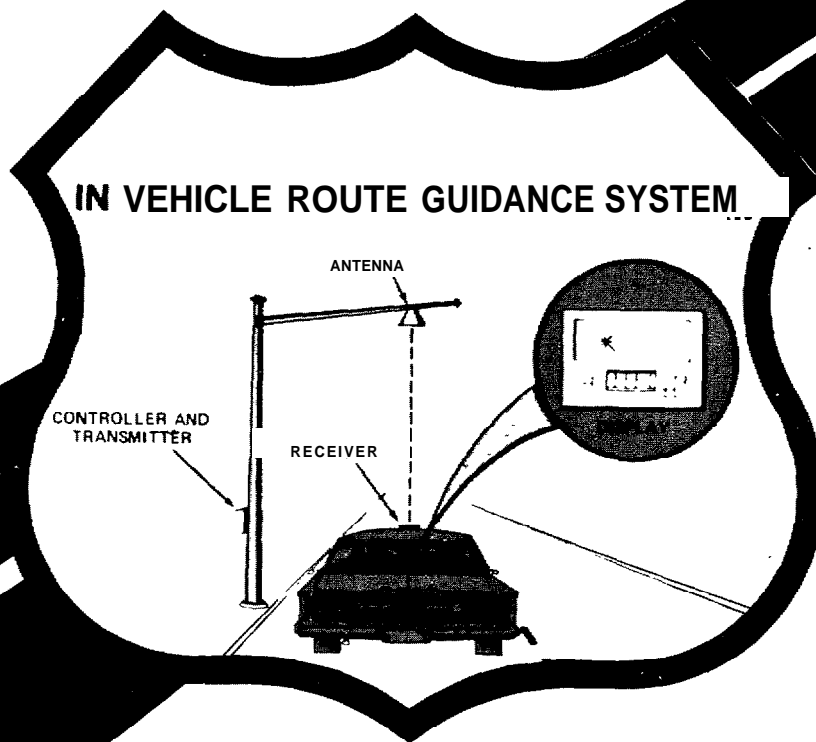


# STUDY OF THE FEASIBILITY AND DESIGN CONFIGURATION FOR IN-VEHICLE ROUTE GUIDANCE

Vol. II  
May 1981  
Final Report



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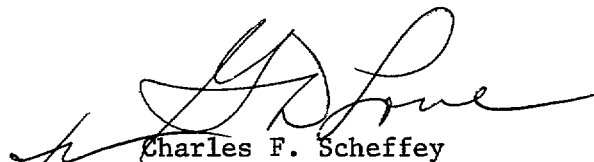
Prepared for  
FEDERAL HIGHWAY ADMINISTRATION  
Offices of Research

## FOREWORD

This report presents the results of a research effort entitled "Study of the Feasibility and Design Configuration for In-Vehicle Route Guidance" performed by Sperry Systems Management Division, Great Neck, New York. The work was conducted for the Federal Highway Administration under Contract Number DOT-FH-11-9522.

The study analyzed the need for and the feasibility of installing an In-Vehicle Route Guidance (IVRG) System in the United States. Several system concepts were studied. The concept recommended for further consideration features information transmission in one direction, from the roadside to each vehicle, using either microwave or optical communications. The study concluded that a system of appropriate design would satisfy a significant portion of the need for route guidance with a favorable benefit to cost ratio.

Basically, the recommended system would allow a driver to encode a specific destination code into the vehicle electronics at the beginning of a trip. The system would provide routing information to the driver via a dash mounted visual display, such that appropriate guidance would be provided from trip origin to destination.



**Charles F. Scheffey**  
Director, Office of Research

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16. Abstract  This study analyzed the need for and the feasibility of installing an In-Vehicle Route Guidance System.  The study concluded that a system of appropriate design would satisfy a significant portion of the need for route guidance with an appropriate benefit to cost ratio and appropriate net benefits.  Several systems were studied and two were considered			

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## SECTION 1

### INTRODUCTION

In the past years a number of programs in this country and abroad have investigated the concept of in-vehicle route guidance and have concluded that such a system is feasible from a technical and human factor's viewpoint and will serve a significant need of the motoring public. The previous studies, however, have not significantly addressed the question as to whether in-vehicle route guidance can satisfy a socioeconomic need in a cost effective manner. It is the purpose of this In-Vehicle Route Guidance Feasibility and Design Study to answer that question, and in the process to define those design and system deployment characteristics which a cost effective system would require.

The report indicates that the majority of route guidance needs relate to urban areas and that a significant "excess" in time and mileage is present. Therefore there is significant improvement potential for an IVRG system. Cost effective IVRG systems may be implemented over a fairly wide parametric range of urban geographies. The system, however, must improve "strategic guidance" in order to effectively satisfy guidance needs. That is, it should plan and control a trip route rather than just provide a local guidance assist at a point or at a limited series of points.

In this study a spectrum of systems was synthesized using both two-way communications between the vehicle and roadside and one-way roadside to vehicle communications with message selection in the vehicle. The communication technologies that were considered for such systems included microwave band, kilohertz band and optical band communications.

The system utilizing one-way data communications was selected, along with a system utilizing a 900MHZ CB radio type of system for an in-depth analysis. In this analysis the technical characteristics, the cost, and the benefits of these systems were identified.

The one-way data communication scheme was found to meaningfully impact the route guidance problem in a cost effective way. Communication schemes using both microwave and optical technology were determined to be feasible. A general program plan for further development of their concept was generated.

Key topics discussed in this report are:

Assessment of route guidance needs

Historical and current IVRG systems

Methodology for estimating of IVRG benefits

Market acceptance of IVRG

Design of candidate IVRG systems

Benefit and cost studies of the candidate systems

Appendices containing detailed information on the topics discussed in the main body of this report are provided.

## SECTION 2

### BACKGROUND - IVRG SYSTEMS

Various IVRG systems have been proposed in the United States, Europe, and Japan during the past several years. These systems were developed in response to differing traffic needs and hence they utilize different techniques and provide several levels of traffic functions.

This section provides background information on several of these IVRG systems. The history and operational features are summarized. In Appendix A a detailed analysis and comparison of five of the previously noted systems are provided in matrix table format.

#### 2.1 THE DAIR SYSTEM

The DAIR (Driver Aid Information and Routing) System <sup>(1)</sup> was developed by the General Motors Corporation in the mid 1960's. This system contains four basic subsystems. They are:

1. Motorist Aid - This subsystem allows the motorist to summon aid from an Aid and Information Center via two-way voice and coded communications over the CB radio band.
  2. Visual Sign Minder - This subsystem reproduces roadside traffic signs on a display panel in the car through magnetic field coupling between the vehicle and magnets mounted in the roadway in a coded pattern.
  3. Audio Sign - This subsystem provides reception over the CB radio of voice messages pertaining to traffic conditions and emergency situations on the road ahead. This subsystem falls under the overall heading of Highway Advisory Radio.
  4. Route Minder - This subsystem provides directional guidance to the motorist via an onboard trip computer. The motorist at the start of his trip, uses a punchcard to load his destination into a computer located in the car. A vehicle's location is determined as it passes over roadway traps containing magnets arranged in a binary code. The arrangement, unique to that location, is decoded by the vehicle's processor which actuates the appropriate instruction on a display unit. The instruction directs the motorist to either continue straight, turn left or turn right. The In-Vehicle Display unit is shared with the visual sign minder subsystem.
- </

Demonstration equipment was produced but no attempt was made to design production equipment,

## 2.2 THE ERGS SYSTEM

The ERGS (Experimental Route Guidance System)(2,3,4,5) was designed by General Motors under contract to the Federal Highway Administration in the late 1960's. This system provides the motorist with directional guidance. In its initial static configuration, ERGS consisted of an in-vehicle display and data entry device and a roadside communication and control unit. The motorist at the start of his trip, enters a five letter code word via thumbwheel switches into a console mounted in his vehicle. As the vehicle approaches an instrumented intersection it receives a trigger from a pre-intersection transmitter. The vehicle's destination is then transmitted via near field radio to the roadside unit containing a processor which computes and then transmits instructions back to the vehicle's display. The display consists of 16 back lighted elements containing symbols and words. The routing instructions are formed by lighting combinations of these elements. A field version of the equipment designated as ERGS II was field tested at an intersection in the Washington, D C. area in 1968. A prototype system was to be installed at 100 intersections in the Washington, D. C, area beginning in late 1969. This system designated ERGS III was to contain circuitry in the roadside units to allow dynamic operation of the system, a capability the earlier systems did not have. In the dynamic mode traffic surveillance would be utilized to provide a traffic responsive capability by remote update of the route selection parameters. This updating capability allowed for the selection of a route with minimum travel time. The program was terminated prior to the installation of the ERGS III system.

- (2) General Motors Research Laboratory, "A Design for an Experimental Route Guidance System - Volume I:- System Description", FHWA PB-197-090 - November 15, 1968
- (3) General Motors Research Laboratory, "A Design for an Experimental Route Guidance System - Volume II - Hardware Description", FHWA Pub. PB-197-091 - November 15, 1968
- (4) General Motors Research Laboratory, "A Design for an Experimental Route Guidance System - Volume III - Driver Display, Experimental Evaluation", FHWA Pub,

## 2.3 THE CAC SYSTEM

The Comprehensive Automobile Traffic Control System (CACS)(6, 7, 8) has been developed by the Japanese "Agency of Industrial Science and Technology, Ministry of International Trade and Industry". This system consists of the following five subsystems.

1. Route Guidance - This subsystem provides directional instructions to the motorist. The subsystem is similar in operation to the ERGS system using nearfield radio as the communications medium between the vehicle and the roadside unit and with route processing occurring in the roadside unit. The roadside units are linked to a control center, over a wire interconnect. Thus the system has a dynamic routing capability.
2. Driving Information - This subsystem is similar to the DAIR visual sign function. In the CAC implementation, roadside signing is displayed on a panel mounted inside the vehicle. The messages are transmitted by the nearfield radio communication technique used in the Route Guidance System.
3. Public Service Vehicle Priority - This subsystem locates and traces equipped public vehicles on a display at the control center. This system also grants priority to emergency vehicles at signalized intersections.
4. Traffic Incident Information - This subsystem transmits advisory messages concerning traffic conditions and emergency situations on the road ahead to the motorist via his car's broadcast radio. Transmitters with limited range are located along the road. Audio messages are transmitted from the control center to the roadside unit where a transmitter and modulator are housed. This system is similar to DAIR's "Audio Sign" subsystem.
5. Route Display Board - This subsystem displays traffic advisory messages on variable message signs mounted along the roadway.

Development of the CAC system started in 1973. A pilot test system covering 103 intersections in a 12 mi<sup>2</sup> (30 km<sup>2</sup>) section of southwest Tokyo has been evaluated.

- 
- (6) Onda, M., "Comprehensive Automobile Traffic Control Project - Part I Outlines of the Pilot Test System", Agency of Industrial Science and Technology, Ministry of International Trade and Industry, Japan
  - (



with a loop antenna mounted under the car receives the message as it passes over an antenna, buried in the roadway. A "Visual Display Unit" mounted in the car displays the appropriate message by illumination of combination of words or the display of numerals. The display contains combinations of words to define the hazard (such as "CONGESTION") gives its location (such as 1 MILE) and advises any action to be taken (such as "KEEP LEFT MAX SPEED 30"). This system, as does ERGS and CAC, utilizes near field radio as the communications medium to the vehicle. Prototype equipment was constructed and tested in the 1970's.

### SECTION 3

#### ASSESSMENT OF ROUTE GUIDANCE NEEDS

This section describes the need for an IVRG system, presents a needs mode3 and discusses the capability of fixed guide signing to satisfy motorist navigation needs.

#### 3.1 Highway Use Characteristics

Table 1 describes the percentage of highway travel on the various facilities as obtained from Reference (13). The relative figures for the entire U.S. system are provided. In addition, the comparative figures for a state (New York) with a higher preponderance of urban travel than the national average is shown.

TABLE 1. 1975 HIGHWAY USE STATISTICS

CLASSIFICATION CATEGORY	VEHICLE MILE % IN CATEGORY NATIONAL	VEHICLE MILE % IN CATEGORY NEW YORK STATE
Interstate Rural	9.3	6.1
Interstate Urban	10.0	11.2
Primary Rural	16.0	14.1
Primary Urban	12.0	17.7
Secondary & Local Rural	11.9	7.1
Secondary & Local Urban	3.6	3.5
Federal Aid Urban	12.2	8.4
Rural - not on FAS*	7.6	

From this data it is seen that most of the VMT (Vehicle Miles of Travel) is in urban areas. In addition, the ratio of total VMT to rural Interstate Highway System mileage is also high. From this data it may be concluded that the bulk of the route guidance needs occur in urban areas, and the higher traffic to roadway mileage ratios tend to make the likely benefit cost relationship from instrumentation in these areas highest. Even the bulk of the guidance problems eventually encountered by motorists travelling the rural Interstate Highway System occur in urban areas as these serve as the principal destinations for these motorists.

The basic data in Table 2 is also obtained from Reference<sup>(13)</sup>. It indicates data on vehicle registrations, miles driven, and drivers' licenses. The following assumptions for the model were based on this data:

- o Most research studies have been performed on passenger vehicle drivers. While these only constitute 80% of the total vehicles and vehicle mileage, all vehicle mileage was assumed to generate a guidance need (the somewhat lower route guidance need for commercial drivers being partly offset by the greater economic penalty for errors).
- o The close to unity ratio of driver licenses and vehicle registrations fortuitously permits an identical quantitative expression for "route guidance need per licensed driver" and "route guidance need per vehicle".

TABLE 2. 1975 MOTOR VEHICLE USE STATISTICS

Motor Vehicle Registrations

Autos - 106,000,000

All\* - 133,000,000

Driver Licenses in effect - 130,000,000



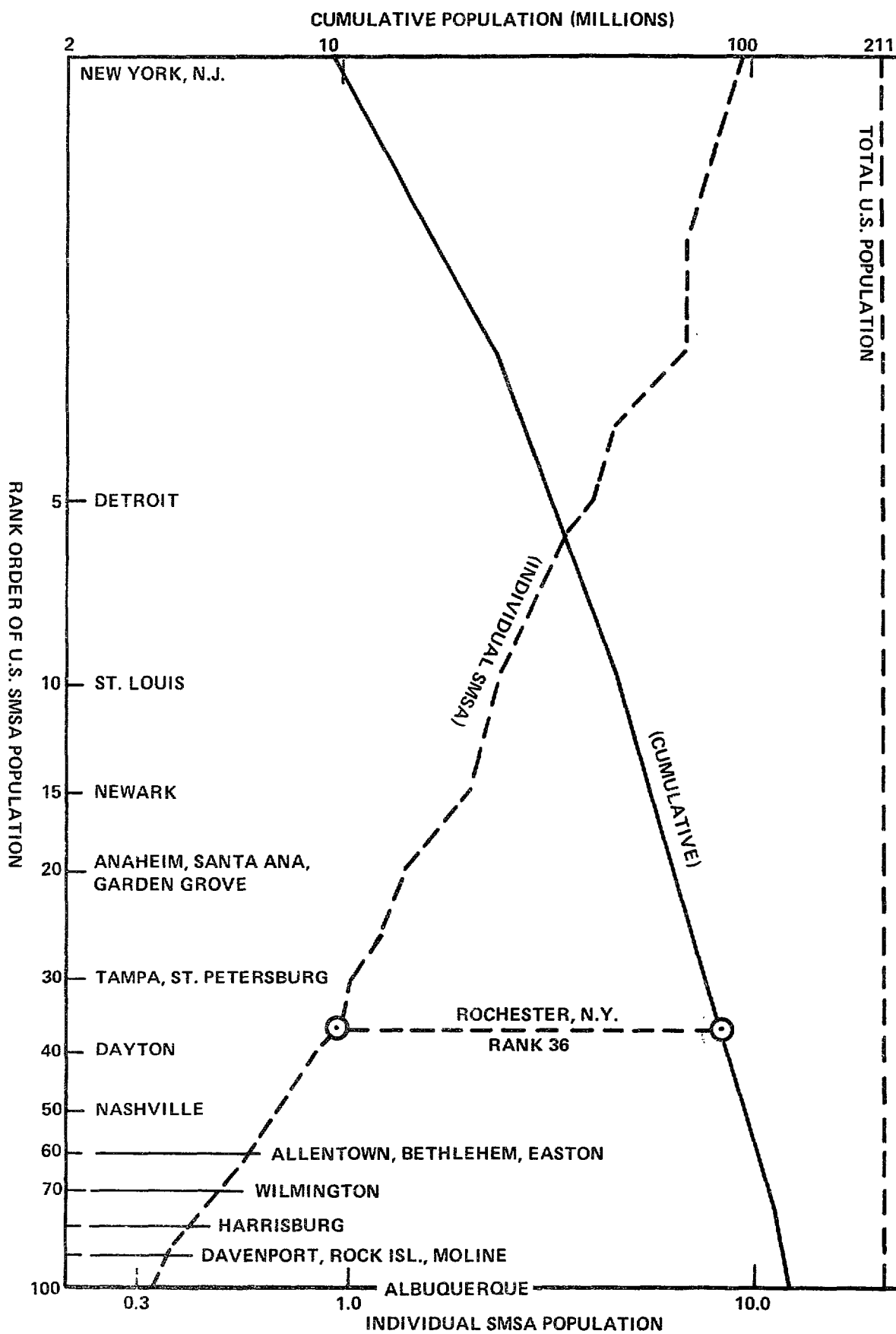
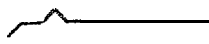


TABLE 3. SOURCES OF MOTORIST NAVIGATION PROBLEMS

<u>Problem Source</u>	<u>General Nature of Problem</u>
1. Driver is unfamiliar with the immediate local area	<u>Local familiarity</u> Driver cannot relate to local highway system
2. Driver does not know location or sequence of major decision points	
3. Driving conditions (light level, sole vehicle occupant, need for repeated reference) preclude successful use of map	<u>Map Problems</u> Driver cannot make use of information normally obtained from road maps
4. Driver does not read maps well or did not have map	
5. Misunderstanding of guide sign message or lack of sufficient guide sign information	<u>Static Information Problems</u> Sign or other written highway information not adequate on a static basis, i.e. the basic information is insufficient or confusing
6. Driver misunderstood designation of highway facility referenced by guide sign. He knew the facility by another name or designation	
7. Street names not posted or not sufficiently large or visible	<u>Dynamic Information Problems</u> Appropriate information is available but the real time driving problems encountered at the moment precluded successful identification and execution of the maneuver
8. Building address numbers not posted or not sufficiently visible or legible	
9. Sign not sufficiently far enough in advance or required action to allow for safe performance or required maneuver	
10. Missed sign because of inattention, information overload, high vehicle blockage, etc.	
11. Driver confused as to appropriate lane or turn because of poor lighting, visibility unexpected geometrics, inappropriate markings or delineation	

TABLE 3. SOURCES OF MOTORIST NAVIGATION PROBLEMS (Continued)

	<u>Other Problems</u>
12. Alternate route information needed to avoid congestion delay	
13. Same as 12 - delay caused by construction	
14. Driver didn't know where access to parking was located	
15. Driver didn't know which parking facilities had available space	
16. Driver was unable to pre-plan (by using maps, personal knowledge, or other information) the best static route to his destination.	
	<u>Limits of Human Analysis</u> The complexities of estimating route length and probable speed lead to a certain level of error in the pre-planning. This is usually not received, even after the journey.

### 3.2.2 Strategic Route Guidance Needs in Urban Areas

Strategic route guidance needs have been separated into three components --

- o Enroute Static Guidance Needs
- o Terminal. Static Guidance Needs
- o Dynamic Guidance Needs

Each of these components is addressed in the following paragraphs.

#### Enroute Static Guidance Needs

The enroute portion of the journey is considered to be that portion from its origin to the vicinity of the destination about 3 mi (4.8 km). For working purposes it was assumed that the enroute trip portion extended to the intersection of major arterials (including freeways) which is closest to the destination,

The studies and data described in numerous References(14, 15, 16,17,18) were reviewed and the following figures were developed to describe what is believed to be a fairly conservative view of enroute travel excess and its reduction potential.

- o Familiar trips - 5 percent time and distance excess
- o Unfamiliar trips - 15 percent time and distance excess
- o Potential reduction in excess resulting from motorists desire for shortest or quickest route - 75 percent

- (14) Armstrong, B.D., "The Need for Route Guidance", TRRL Supplementary Report 330, Transport & Road Research Laboratory 1977
- (15) Gordon, D. & Wood, H., "How Drivers Locate Unfamiliar Addresses - An Experiment. in Route Finding", Public Roads June 1970



TABLE 4. ENROUTE URBAN AREA TRIP ANALYSIS

Average Trip Length Mi.	Fraction of Trips	Fraction of Urban Vehicle Miles Travelled	Cumulative Enroute Mileage Fraction	Average Vehicle Mileage in Urban Areas (National)	"Familiar" Urban Enroute Mileage (National)	"Unfamiliar" Urban Enroute Mileage (National)
<2	.45	.120	.120	662	635	26
2-4	.22	.176	.296	972	855	116
4-6	.12	.160	.456	883	706	194
6-8	.08	.149	.605	822	600	222
8-10	.06	.144	.749	795	532	262
10-12	.03	.088	.837	486	296	190
12-14	.02	.069	.906	381	221	156
14-16	.01	.040	.946	221	119	102
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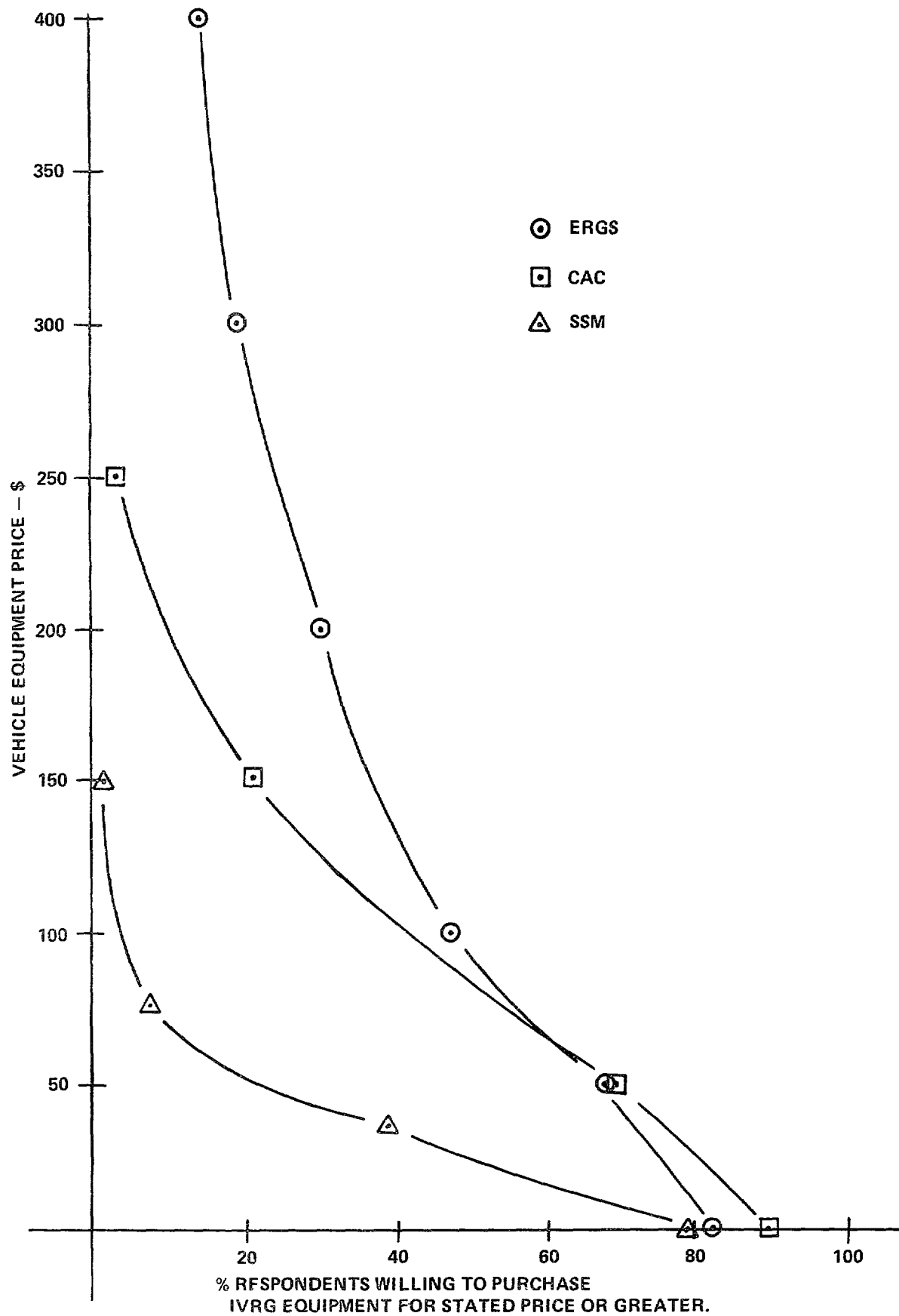












Surveys of this sort are subject to two types of errors. They might tend to overestimate the sales price for variations of fairly conventional products because the customer, when confronted with the purchase decision, simply fails to pay the price. On the other hand, when a radically new product is involved, market surveys often underestimate the demand because actual exposure to the product might be necessary before the customer can perceive the benefits.

Basing the benefit cost studies on the demand curve of the SSM survey leads to a basically conservative approach to IVRG design. Candidate systems which show positive net benefits for this curve are assured of much better benefit/cost performance for the less conservative curves. Thus this curve was used in the studies described in Section 8.





GUIDANCE COMPONENT – STRATEGIC  
ENROUTE

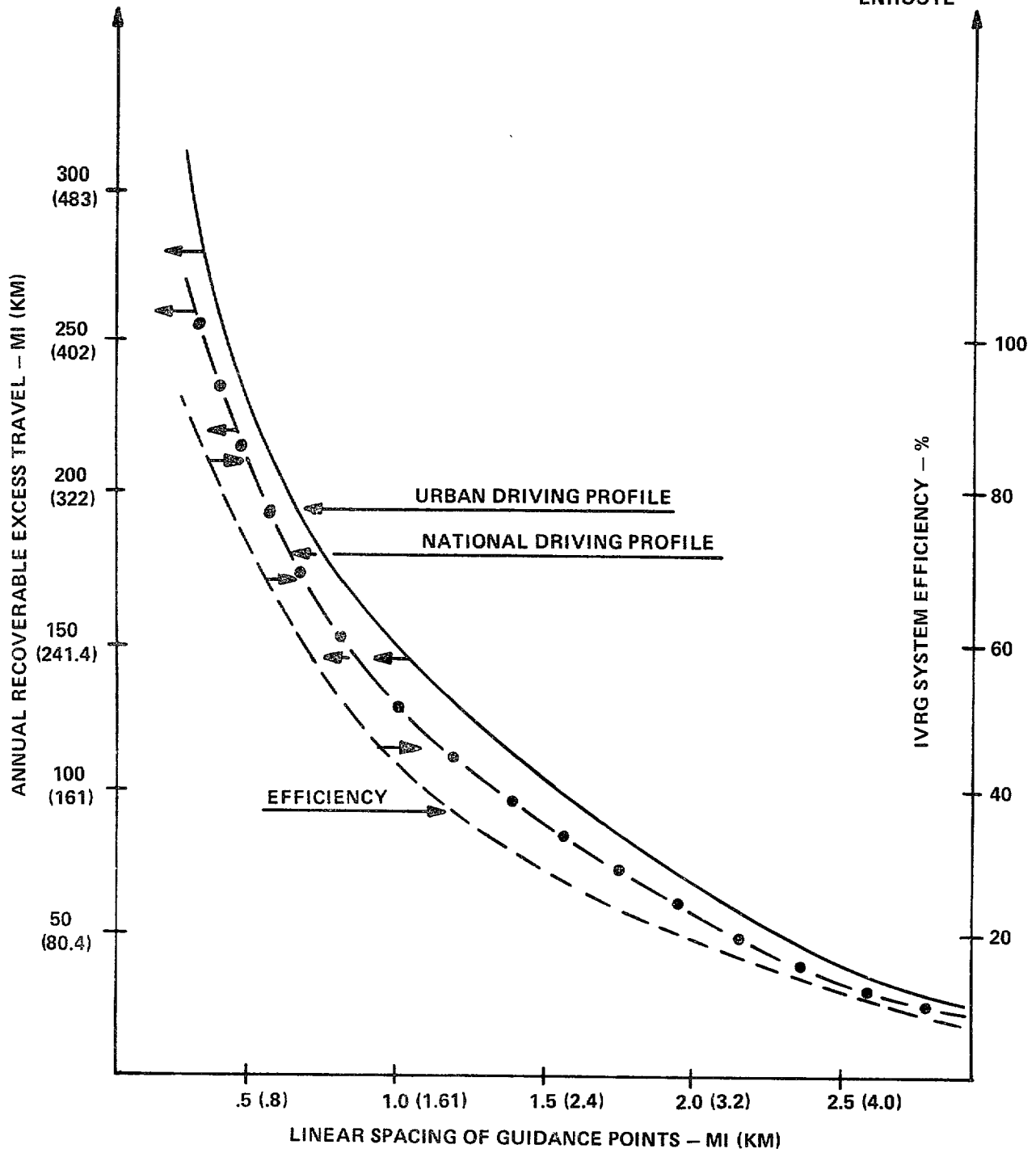












TABLE 11. IVRG SYSTEM VARIATIONS AND CHARACTERISTICS

IVRG SYSTEM VARIATIONS	SYSTEM COVERAGE LEVEL			SYSTEM DEPLOYMENT AREA INTENSITY			TYPE OF NEED SATISFIED (SEE CODE)									
	SYSTEM CLASS	LOCATION SPECIFIC	URBAN AREA COVERAGE	NAT'L COVERAGE	LOCATION SPECIFIC	MODERATE	HEAVY	LANE GUIDNCE	EXIT RAMP INIT PT	EXIT RAMP FINAL PT	GUIDNCE FWY ENT	INTERS DRCTN	DIRECTION THRU 1-WAY SYSTEM	CONCESSION	TERMINATION	OPTIMAL ROUTE
1. POINT LOCATION COMMON MESSAGE AUDIO	1	X			X			P	P	P	N	Limited Capability	N	N-P	N	N
2. AREA-WIDE COMMON MESSAGE AUDIO	1		X		X			N	P	N	N	H	N	N-P	N	N
3. SYSTEMS 1 & 2 COMBINATION	1	X	X		X			P	P	P	N	Limited Capability	N			

TABLE 11. IVRG SYSTEM VARIATIONS AND CHARACTERISTICS (Continued)

IVRG SYSTEM VARIATIONS	SYSTEM CLASS	COMMUNICATION TO VEHICLE		DATA INSERTION		MOTORIST INST TECHNIQUE		TRAFFIC RESPONSIVE*	
		ONLY WAY	TWO WAY	NONE OR MINIMAL	LIMITED	MAJOR	READ SIGNS	VEHICLE CARRIED MATERIAL	NO YES
1. POINT LOCATION COMMON MESSAGE AUDIO	a b	SHORT RANGE LINK	NONE OR ENABLE & TUNING	X			X		X
2. AREA-WIDE COMMON MESSAGE AUDIO	a b	LONG RANGE LINK	NONE OR ENABLE & TUNING	X			X		X
3. SYSTEMS 1 & 2 COMBINATION	a b	X	NONE OR ENABLE & TUNING	X			X		X
4. LIMITED MOTORIST MESSAGE SELECTIVITY	a b	X					X		X
5. SIGNIFICANT MOTORIST MESSAGE SELECTIVITY	a b	X						X	X
6. FULL MESSAGE SELECTION, MODERATE DEPLOYMENT	a								





















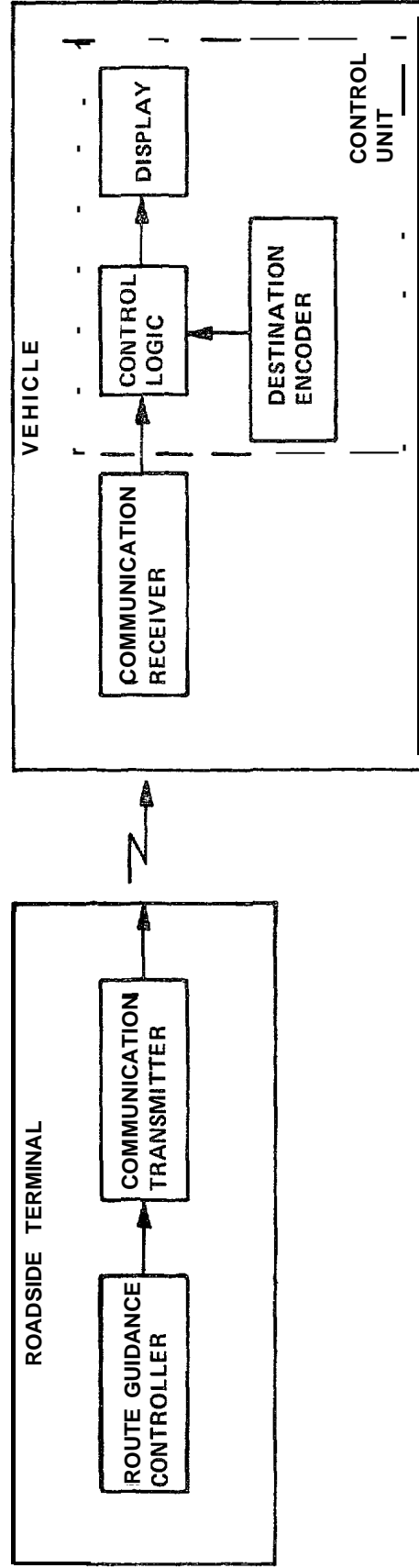
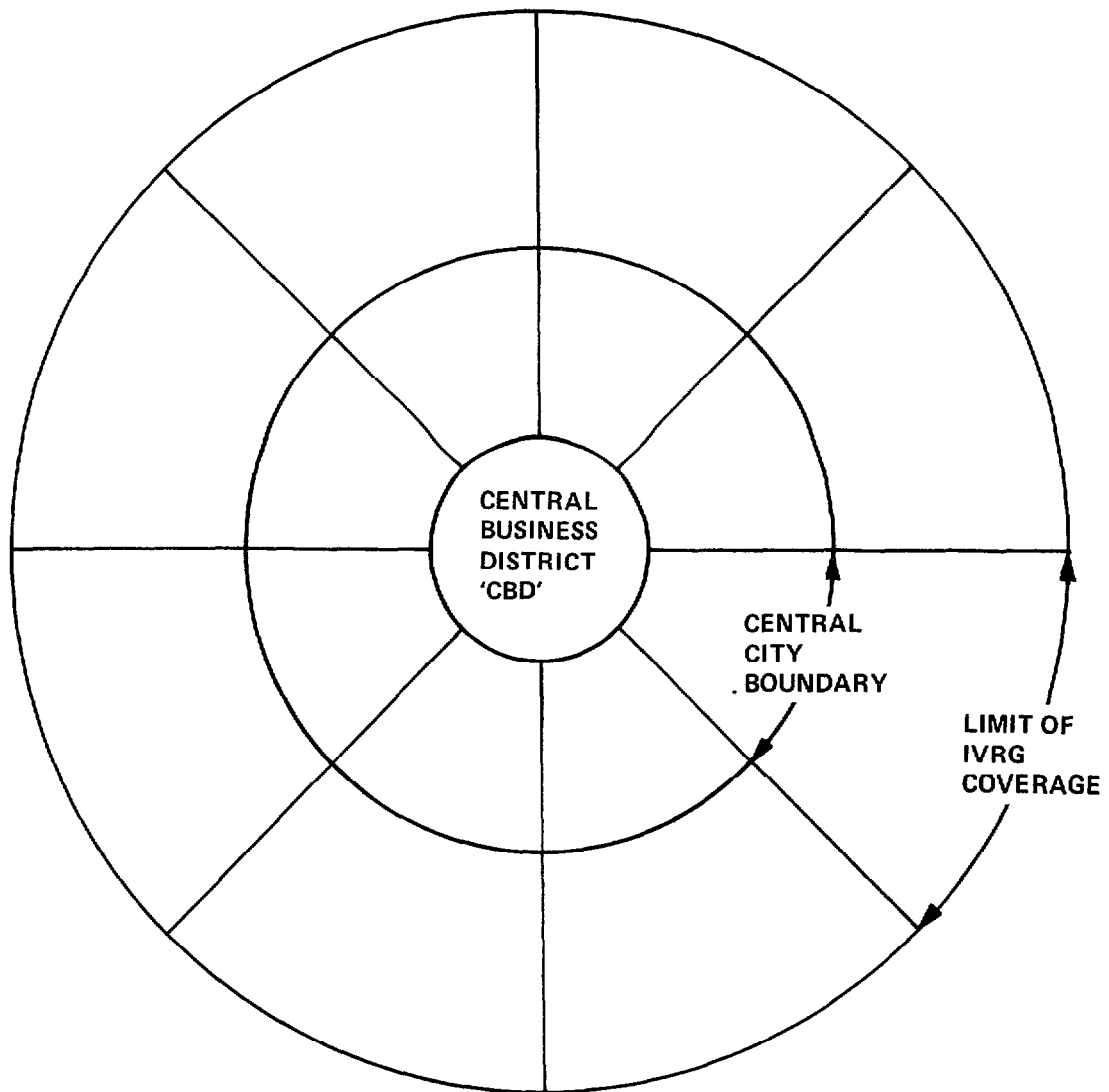


Figure 4. One Way Data Communication Approach - IVEG (Block Diagram)







NOTE SPACING OF RADIAL BOUNDARIES IS DEPENDENT ON DENSITY OF GUIDANCE POINTS.

Figure 6. IVRG Urban Area Map

TABLE 13. GUIDANCE POINT REQUIREMENTS

Metropolitan Region	Chicago	Detroit	Washington	Baltimore	Denver
Central City Area (sq mi)	223	138	61	78	95
Guidance points in central city @ 2/sq mi	445	276	123	157	190
Area of Region less central city (sq mi)	686	480	394	292	304
Guidance points in suburban area @ 1.25/sq mi	858	600	493	365	380
Number of non CBD sectors	8	8	7	6	6
Number of guidance points in CBD	163	110	120	87	60
Total number of guidance points	1466	986	736	609	630
Number of guidance points per remote sector	163	109	88	87	95

NOTE: 1 sq mi = 2.6 sq km



TABLE 14. IVEG CODING SCHEME

	DIGITS				Code info provided by
	1	2	3	4	
<u>Principal Function</u> Metropolitan Area guidance	1 thru 9	0, 1	0 thru 9	0 thru 9	Metro Area Guidance Chart
<u>Special Functions</u> (a) Remote Metropolitan Areas	0	2	0 thru 9	0 thru 9	All printed motorist aids
(b) Rural interstate exits	0	3	0 thru 9	0 thru 9	State highway maps and oil co. maps
(c) Local functions (parking, national parks, airports, special roadway networks)	0	3	0 thru 9	0 thru 9	Road signs or special printed material









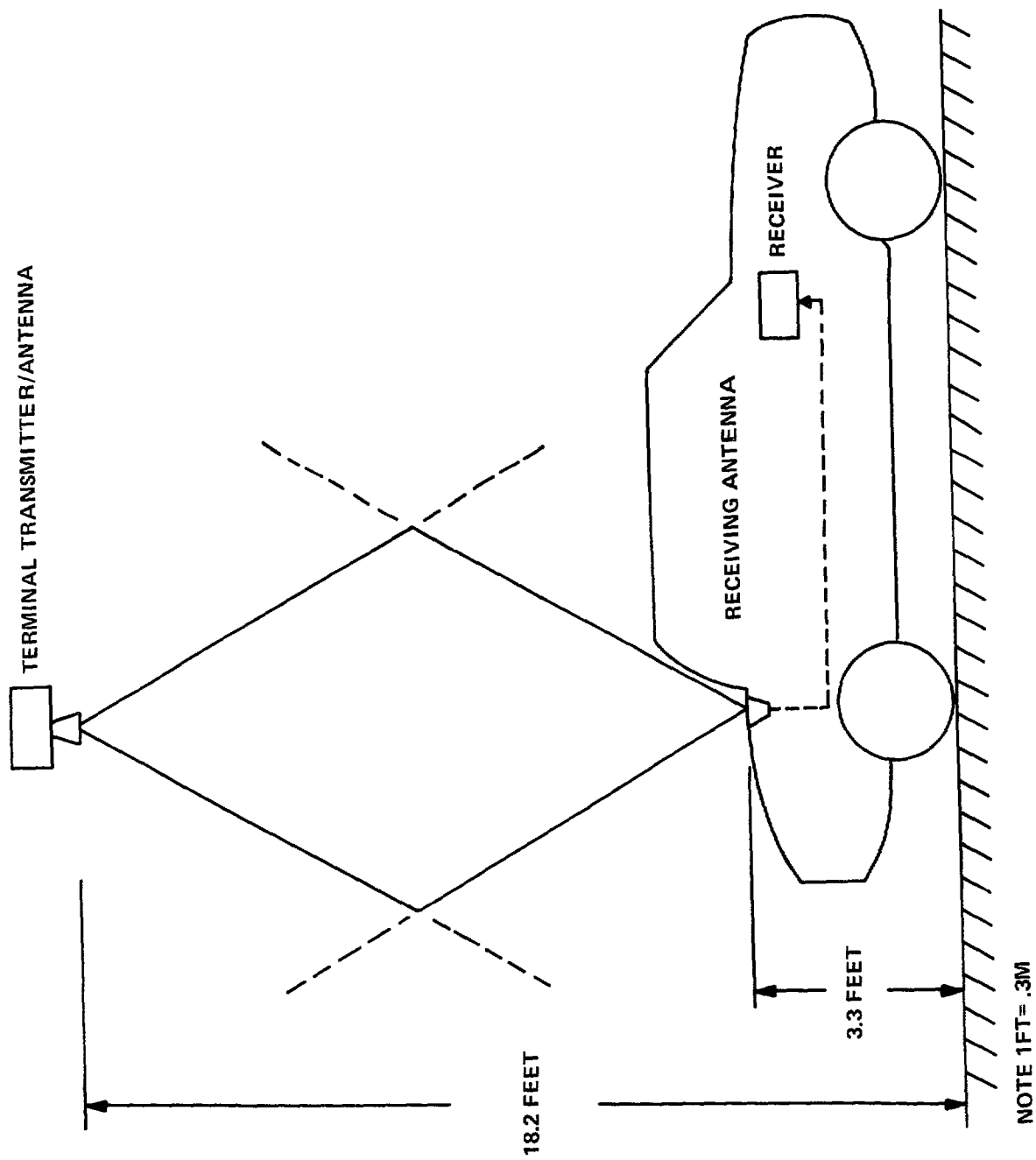


Figure 8. Point-to-Point Link Configuration Using Directive Antennas



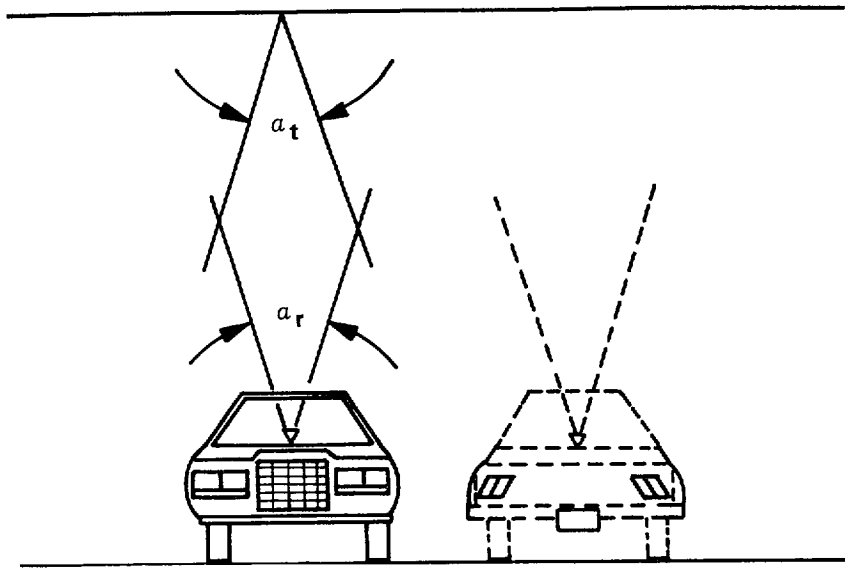


Figure 9. Ideal Antenna Radiation Pattern Orthogonal to Vehicular Motion. Note that the vehicle in the Opposing Lane Will Not Receive the Signal Even While in the Worst Case Position (against the centerline).

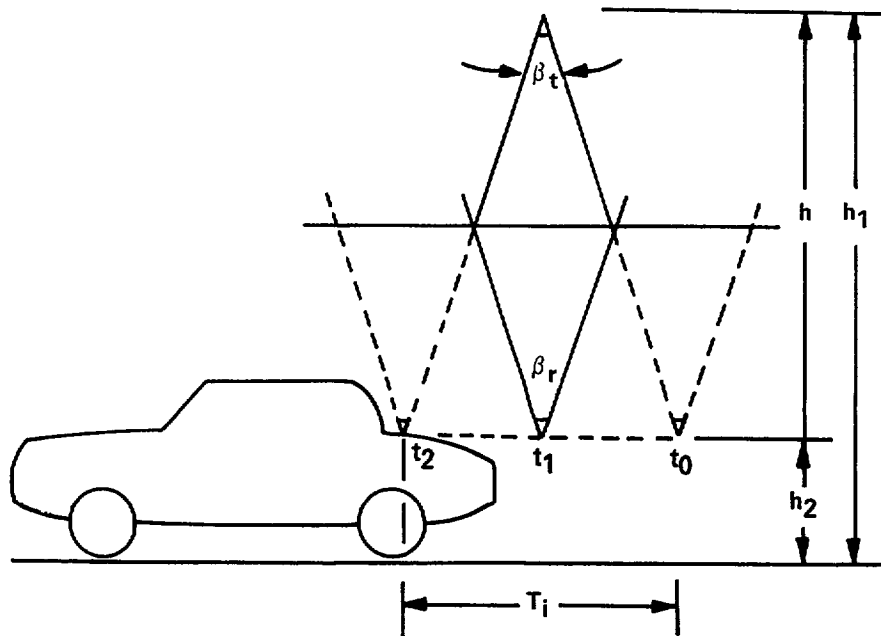


Figure 10. Ideal Antenna Radiation Pattern in the Direction of Vehicular Motion. Intercept Time ( $T_i$ ) is Defined as Leading Edge Entry to Trailing Edge Exit Time

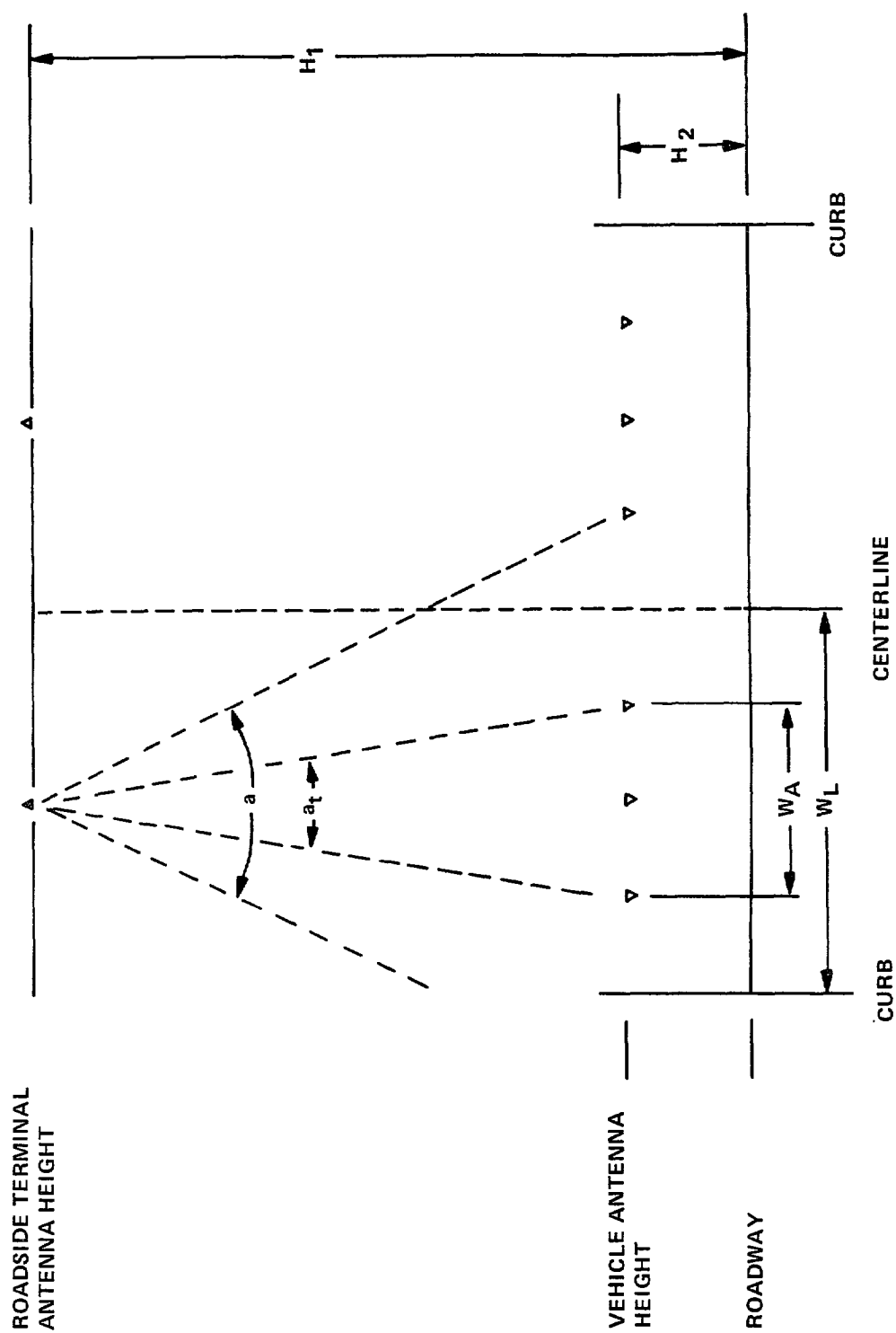


Figure 11. Antenna Beamwidth Analysis Orthogonal to Vehicle Motion

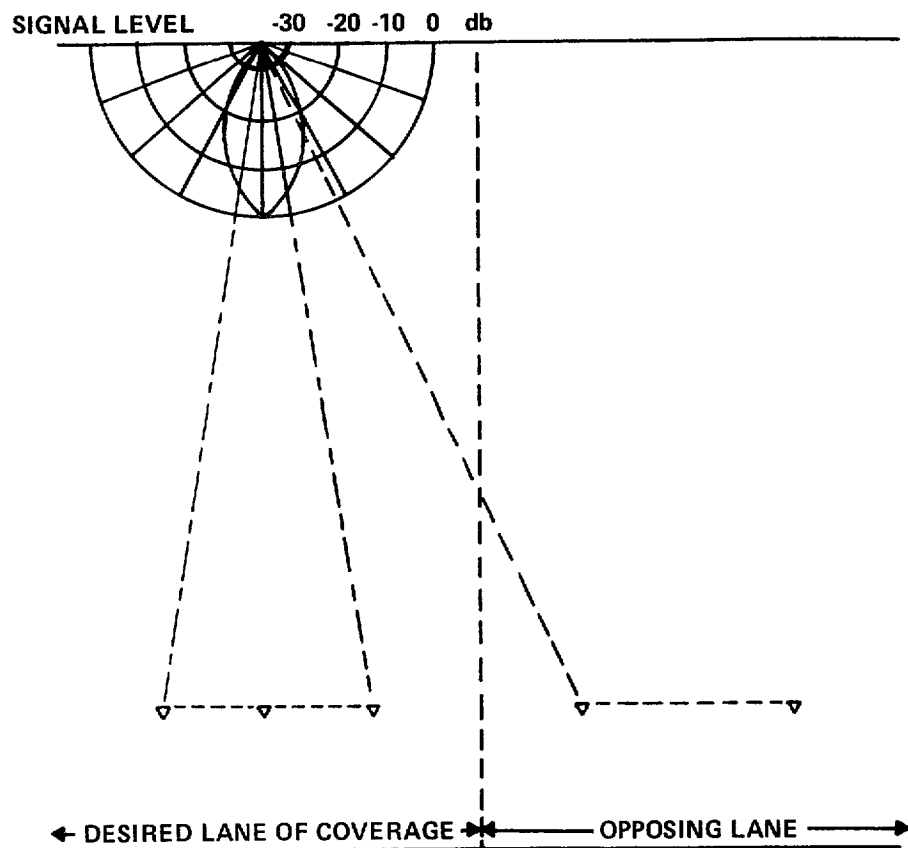


Figure 12. Radiation Pattern of the Transmitting Antenna





























































































































































































































































































